ANSWERS Solubility with change in pH

1) $Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2OH^{-}(aq)$
When pH is less than 4 / low, $[OH^{-}]$ is decreased due to the reaction with H_3O^{+} to form water,
$H_3O^{+} + OH^{-} \rightarrow H_2O$
so equilibrium shifts to the right to produce more $[OH^{-}]$, therefore more $Zn(OH)_2$ will dissolve.

When pH is greater than 10 / high, then more OH^{-} is available and the complex ion (zincate ion) will form.
$Zn(OH)_2(s) + 2OH^{-} \rightarrow [Zn(OH)_4]^{2-}$
OR $Zn^{2+} + 4OH^{-} \rightarrow [Zn(OH)_4]^{2-}$
This decrease in $[Zn^{2+}]$ causes the position of equilibrium to shift further to the right, therefore more $Zn(OH)_2$ dissolves.

2) a) i) $[H_3O^{+}]^2[S^{2-}] = 1.1 \times 10^{-23}$
$[H_3O^{+}] = 10^{-4.20}$ when pH = 4.20
(remember from Year 12 Chemistry:
$pH = -\log [H_3O^{+}]$
therefore...
inverse log – pH = $[H_3O^{+}]$
$[H_3O^{+}] = 6.31 \times 10^{-5}$ mol L^{-1}

$$[S^{2-}] = \frac{1.10 \times 10^{-23}}{\left(10^{-4.20}\right)^2}$$

$= 2.76 \times 10^{-15}$ mol L^{-1}

ii) $K_s = [Fe^{2+}][S^{2-}]$
$4.90 \times 10^{-18} = [Fe^{2+}] \times 2.76 \times 10^{-15}$
$[Fe^{2+}] = 1.78 \times 10^{-3}$ mol L^{-1}
i.e., solubility of FeS is 1.78×10^{-3} mol L^{-1} when the pH of the solution is 4.20.

3) When hydrogen sulfide is bubbled through a solution containing Cu^{2+} and Zn^{2+} the following equilibrium is established.

$$H_2S \rightleftarrows 2H^{+} + S^{2-}$$

As the pH of a saturated solution (by the addition of HCl) decreases, the equilibrium shifts in the reverse direction reducing $[S^{2-}]$.

For precipitation to occur IP>K_s. Hence only the metal sulfide with the lowest K_s will precipitate. In this case CuS as IP(CuS)> K_s(CuS). The ZnS will not precipitate. As the pH then decreases $[S^{2-}]$ will increase. This enables metal sulfides with larger values of K_s in this case ZnS, to precipitate as well as the CuS.

4) When the pH is decreased, $[H_3O^{+}]$ will increase. The H_3O^{+} will react with the OH^{-} and therefore remove them from the equilibrium. This will cause the reaction to replace some of the removed OH^{-}. As a result more $Fe(OH)_3$ will dissolve, so decreasing the pH will increase the solubility of $Fe(OH)_3$.

5) Raising the pH will increase the concentration of OH^{-} ions. This will initially cause additional precipitate to form. Once the pH has been increased sufficiently (enough OH^{-} has been added) the formation of a complex ion with Zn^{2+} will occur, lowering OH^{-} ion concentration in solution. Thus the precipitate will redissolve as a complex ion and less precipitate will be at the bottom of the test tube.

6) More silver chromate dissolves.
Ammonia complexes with silver ions. $Ag^{+} + 2NH_3 \rightarrow [Ag(NH_3)_2]^{+}$

This removes silver ions from the equilibrium mixture. The silver chromate equilibrium will shift to the RHS.
Note: *Accept NH_3 solution increases OH^- ion concentration so that Ag^+ reacts with this and precipitates out of solution (as Ag_2O). Hence, less Ag^+ in solution results in more Ag_2CrO_4 dissolving.*

7) $Al(OH)_3(s) \rightleftharpoons Al^{3+}(aq) + 3\ OH^-(aq)$

Acidic conditions

When the pH is less than 4, $[H_3O^+] > [OH^-]$ and the **$[H_3O^+]$ ions react with OH^-** ions from $Al(OH)_3$.

ie $H_3O^+ + OH^- \rightarrow 2H_2O$

(OR $Al(OH)_3(s) + 3\ H_3O^+ \rightarrow Al^{3+}(aq) + 6\ H_2O$)

The decrease in $[OH^-]$ from the solubility equilibrium causes the position of equilibrium to shift further to the right so that more $Al(OH)_3$ is dissolved.

Basic conditions

When the pH is greater than 10, $[H_3O^+] < [OH^-]$ and the OH^- ions react with Al^{3+} ions from $[Al(OH)_4]^-$

ie $Al^{3+} + 4\ OH^- \rightarrow [Al(OH)_4]^-$

(OR $Al(OH)_3(s) + OH^- \rightarrow [Al(OH)_4]^-$)

The decrease in $[Al^{3+}]$ from the solubility equilibrium causes the position of equilibrium to shift further to the right so that more $Al(OH)_3$ is dissolved.

8) $NH_3(aq) + H_2O \leftrightarrow NH_4^+(aq) + OH^-(aq)$

As NH_4Cl dissolves $[NH_4^+]$ is increased. This causes the equilibrium to move to favour formation of reactants so that $[OH^-]$ is decreased. As $[OH^-]$ is decreased, $[H_3O^+]$ is increased and pH is decreased.

9) $[Mg^{2+}][OH^-]^2 > 7.10 \times 10^{-12}$
$0.555 \times [OH^-]^2 > 7.10 \times 10^{-12}$
$[OH^-] > 3.58 \times 10^{-6}$
Minimum pH = 8.55